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The influence of agriculture in the process of population integration and cultural interaction during the Eastern Zhou Period in central-south, Inner Mongolia: Carbon and nitrogen stable isotope analysis of human bones from the Dabaoshan cemetery, Helingeer County

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Abstract Central-south Inner Mongolia, China, is highly sensitive to the cultural interactions between sedentary agriculturalists and nomadic pastoralists during the Eastern Zhou Period (770–256 BC). The previous pattern of multiple cultures and diverse ethnic groups has been transformed to the increasingly dominated cultural system of Central Plain since the middle and late Warring States Period, when the states of Zhao and Qin have conquered the most parts of central-south Inner Mongolia. However, the variation of subsistence strategies during this historical process has never been evaluated. Particularly, as the typical representative of Central Plain cultures, the effect of intensive millet agriculture is still unknown in the process of population integration and culture interaction. Thus, to explore the shift of subsistence pattern, carbon and nitrogen stable isotope analysis of bone collagen from Dabaoshan site (410–180 BC) have been performed. The isotopic result indicates a large amount of C_4-based animal protein consumed by Dabaoshan humans. According to the archaeological backgrounds, we propose the Dabaoshan persons intensively relied on the millet agriculture and developed the agro-pastoral economy, which hinted the comprehensive influences from Central plain civilizations in late Warring States Period. Further compared with other published isotopic data in the same region during different periods, we suggest the millet agriculture has played the positive role in the process of population integration and culture fusion in central-south Inner Mongolia during the Eastern Zhou Period.

Keywords Dabaoshan cemetery, Central-south Inner Mongolia, Millet agriculture, Carbon and nitrogen stable isotope

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1. Introduction

Central-south Inner Mongolia, China, is a region that extends northward to the edge of the Yinshan Mountains, southward to the Ordos highland, westward to the Hohhot plain and eastward to the mountain basins near Lake Huangqihai. This distinctive geography contributes to the importance of this region where cultural and ethnic conflicts, interactions and

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integrations occurred between the peoples of the Central Plain and northern steppe (Tian, 1997; Lin, 2008; Wuenyuesitu, 2007; Yang, 2004; Yang et al., 2016).

According to the historical literature, many ethnic groups controlled central-south Inner Mongolia during different stages of the Eastern Zhou Period such as: Huaxia, Rongdi, Huns and Linhu. The first were the Rongdi who were the most important ethnic groups in northern China during the Spring Autumn Period (770–476 BC) (Lin, 1996; Yang, 1999). Historical literature like Zhao Aristocratic Family and Huns Biographies in Records of the Grand Historian, written by Si Maqian, depicted the Huns and Linhu groups settled this area roughly beginning from the Warring States Period (475–221 BC). In 306 BC, Zhao State, one of Seven Warring States during this time, conquered the Rong and the Dai and this resulted in a northward expansion after defeating the northern tribes of Linhu and Loufan (parts of the groups of Rong and Di). Meanwhile, Zhao State built the Great Wall from the Dai to the Yinshan Mountains, establishing the Gaoque Fortress and naming the new territory as counties of Yunzhong, Yanmen and Dai, which were also attributed to the gradual control of lands in central-south Inner Mongolia. Later, about 236 BC, the Qin State conquered the lands of Yunzhong County, but the previous customs were followed, like still using the name of Yunzhong County. This event has been documented in the Shuijing Zhu, written by Li Daoyuan. In summary, the northward expansions conducted by the states of the Central Plain changed the composition of the ethnic groups in central-south Inner Mongolia. The changing ethnic pattern was also depicted in the chapter of geography in Hanshu, written by Ban Gu, which stated: "Counties like Dingxiang, Yunzhong and Wuyuan were previously managed by Rongdi groups, then the immigrants from Zhao, Qi, Wei and Yan (the states of the Central Plain) were increasingly growing".

Recently, numerous archaeological excavations and research projects focused on central-south Inner Mongolia have provided new information on the population composition and cultural variation in this region (Lin, 2008; Cao, 2006; Wang, 2011; Yang, 2009; Yang et al., 2016; Shan, 2015). First, the physical anthropological characteristics of the indigenous populations were named as the type of ancient northern China, while the type of the ancient Central Plain, which had the skeletal features of immigrants from the Central Plain, appeared from the middle and late Neolithic Age. After the late Spring Autumn Period, nomadic populations, with the skeletal characteristic of the ancient Mongolian type, expanded from the northern steppe into central-south Inner Mongolia (Zhang et al., 2010a; Zhu, 2002), which also introduced the nomadic pastoral material cultures such as: interring a great deal of animals, metal weapons, tools and harnesses as burial goods. These new arrived customs have been discovered in the sites of Yaozi, Xindianzi and Taohongbala (Tien, 1976; The Institute of Archaeology, Inner Mongolia, 1989; Cao et al., 2009; Wuen, 2002). Moreover, the composition of the residents, including indigenous populations, nomadic persons from the northern steppe and immigrants from the Central Plain, has become increasingly mixed, which accelerated the process of population integration and cultural interaction in central-south Inner Mongolia. Finally, from the middle Warning States Period to the Qin Dynasty, the cultures of the Central Plain became more and more dominant. The excavations at the Maoqinggou cemetery and Yingniugou cemetery suggest that there was an increasing number of immigrants from the Central Plain, as a result of the new burial ceremony from the Central Plain arriving and flourishing at these sites (Inner Mongolian Relics Team, 1984; Cultural Relics Work Team of Inner Mongolia, 1986; Inner Mongolia Autonomous Institute of Cultural Relics Archaeology et al, 2001; Yang et al., 2009). In summary, the cultures of the Central Plain were well developed (like Tuchengzi cemetery and Jiangjungou cemetery) in the east of the Hohhot plain, with both indigenous and the nomadic cultures disappearing. Whereas, to the west of the Hohhot plain, the cultural factors of the Central Plain were gradually emerging and the nomadic system still survived after a series of significant changes (like Aluchaideng cemetery) (Shan, 2015; Gu, 2010; Archaeological Institute of Inner Mongolia et al., 2004; Archaeological Institute of Inner Mongolia; 2006).

In summary, the interactions between settled agricultural civilization and nomadic pastoral cultures in central-south Inner Mongolia were attributed to mixed ethnic groups as well as the diverse material cultures during Eastern Zhou Period. However, the existing researches mainly focused on the cultural variations and complex physical anthropological indexes (Lin, 2008; Cao, 2006; Wang, 2011; Yang, 2009; Yang et al., 2016; Shan, 2015; Zhang et al., 2010a; Zhu, 2002; Gu, 2010). As the typical representative of Central Plain culture, the influence of millet agriculture on population integration and culture interaction has never been evaluated in central-south Inner Mongolia.

Today carbon and nitrogen stable isotope analysis of human bones from archaeological sites have been routinely used to reconstruct the dietary patterns of an individual, and can further reveal the proportions of agricultural economy in subsistence strategies. This technique has already been successfully used to document the agricultural activities in agropastoralism economies during the Bronze Age in Central Asia (Murphy et al., 2013; Svyatko et al., 2013; Matuzeviciute et al., 2015; Lightfoot et al., 2013, 2015). Another important study is about the shift of economy and culture of the Tuoba Xianbei during their southward migration (Zhang et al., 2011, 2013; Zhang et al., 2015). Therefore, the carbon and nitrogen stable isotope analysis of human bones from the Dabaoshan cemetery in Helingeer County, central-south Inner Mongolia will be performed here, aiming to reveal the human diets and lifeways during the late Waring States Period. Further, referencing the published isotopic data (Gu, 2010; Zhang et al., 2006; Zhang, 2010), the influence of millet agriculture on population integration and cultural interaction during the Eastern Zhou Period in central-south Inner Mongolia will be discussed.

2. Material and methods

2.1 Archaeological background and selected samples

Excavated by Inner Mongolia Normal University in 2011, the Dabaoshan cemetery is located in the hills of Helingeer County, close to the Hunhe River in the north and the Manhanshan Mountains in the east, south and west (Figure 1). In total, 51 earthen pit tombs during the late Warring States Period (410–180 BC), were excavated (Zhang, 2015). Most of the individuals were buried in a supine position but with different burial directions. The majority of the burial directions are north-south oriented (35 tombs), but 15 tombs are aligned in an east-west direction as well as 1 tomb in a northeast-southwest direction. In addition, the burial artifacts, including pottery pots, pottery vases, bronze mirrors, seals, jade and agate jewelry suggest strong cultural influences from the areas of the Central Plain. Based on the above typological analysis of pottery and burial customs, the Dabaoshan cemetery was likely a graveyard used by the persons of the Zhao State during the late Warring States Period (College of History and Culture of Inner Mongolia Normal University et al., 2013; Yu et al., 2015). However, the study of the physical anthropology of the skeletons suggest that the Dabaoshan individuals were a mix of both the ancient Central Plain type and the ancient northern China type, which might be the result of a long term integration of indigenous people and Central Plain immigrants (Zhang, 2015).

In total, 44 skeletons were discovered and we selected 41 individuals for isotopic analysis. The archaeological and anthropological backgrounds are presented in Table 1, including the tomb number, burial direction, gender, age etc. (Zhang, 2015; College of History and Culture of Inner Mongolia Normal University et al., 2013; Yu et al., 2015).

2.2 The preparation of collagen

The bone collagen was prepared based on a modified version of Richard et al. (1999). About 1 g bone was extracted from the femur and mechanically cleaned. The bones were placed in 0.5 mol/L HCl at 4°C to decalcification and were refreshed every 2 days until the bone samples turned soft and stopped bubbling. Then, the residues were washed by deionized water until neutrality and rinsed in 0.125 mol/L NaOH for 20 h at 4℃. Finally, the remains were washed to neutrality again and immersed in 0.01 mol/L HCl to gelatinization at 70℃ for 48 h. After filtration, the residues were freeze-dried for 48 h to obtain collagen. Finally, the yield of collagen was calculated through the collagen weight divided by the bone sample weight (Table 1).

2.3 The measurement of collagen

The elemental contents and stable isotopic data of carbon and nitrogen in bone collagen was measured by an IsoPrime 100 IRMS coupled with Elementar Vario located in Archaeological Stable Isotope Laboratory of the Department of Archaeology and Anthropology, University of Chinese Academy of Sciences. The Sulphanilamide is used as the standard to measure the elemental compositions of C and N. The international stable isotopic standards are IAEA-600, IAEA-N-2, IAEA-CH-6, USGS-40 and USGS-41, which are

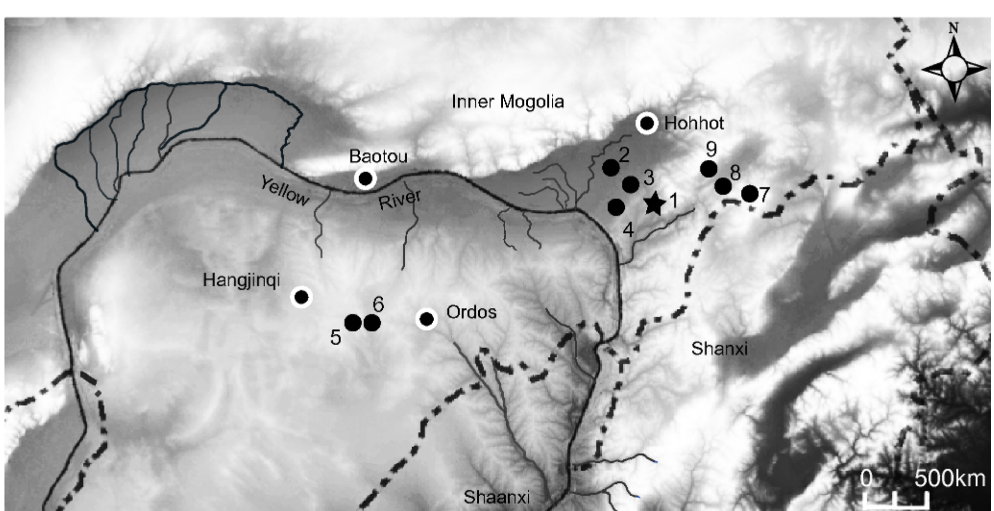

Figure 1 The location of Dabaoshan cemetery. 1. Dabaoshan cemetery; 2. Tuchengzi cemetery; 3. Xindianzi cemetery; 4. Jiangjungou cemetery; 5. Taohongbala cemetery; 6. Aluchaideng cemetery; 7. Maoqinggou cemetery; 8. Yinniugou cemetery; 9 Yaozi cemetery.

Table 1 Archaeological contexts and isotopic results of the bones (41) from the Dabaoshan cemetery

Lab No.	Context	Gender	Age (yr)	Burial direction	C (%)	N (%)	δ^{13}C (‰)	δ^{15}N (‰)	C/N	Yield (%)
DBS-1	M1	Male	35–40	N-S	41.8	15.4	−8.1	10.7	3.2	12.3
DBS-2	M2	Female	25–30	E-W	42.4	15.6	−8.4	9.6	3.2	10.3
DBS-3	M3	Male	25–30	N-S	41.7	15.4	−8.2	9.8	3.2	4.5
DBS-4	M4	Male	40–45	N-S	44.2	16.3	−9.9	9.2	3.2	6.4
DBS-5	M5	Male	35±	N-S	41.9	15.3	−8.1	11.2	3.2	7.8
DBS-6	M6	Female	40±	N-S	44.9	16.5	−8.8	10.7	3.2	9.2
DBS-7	M7	Male	35–40	E-W	42.0	15.4	−8.5	9.6	3.2	6.7
DBS-8	M8	Male	40±	N-S	48.2	14.4	−10.9	10.3	3.9	9.1
DBS-9	M10	Male	25±	N-S	41.3	15.2	−10.2	10.8	3.2	6.0
DBS-10	M11	Male	40±	N-S	41.4	15.3	−7.6	9.8	3.2	5.7
DBS-11	M13	Male	30–35	E-W	43.0	15.9	−7.6	10.3	3.2	7.5
DBS-12	M14	Male	35±	N-S	40.5	15.0	−8.2	10.1	3.2	3.9
DBS-13	M15	Female	40–45	N-S	44.6	16.4	−9.3	10.6	3.2	2.8
DBS-14	M16	Male	40±	N-S	42.9	15.8	−8.6	10.6	3.2	3.6
DBS-15	M17	Female	25–30	N-S	42.0	15.5	−8.5	10.8	3.2	4.6
DBS-16	M18	Male	25–30	N-S	41.9	15.6	−8.1	7.8	3.1	3.2
DBS-17	M19	Female	40±	N-S	42.9	15.7	−10.6	9.5	3.2	4.8
DBS-18	M20	Male	30–35	N-S	43.8	16.1	−8.7	9.4	3.2	3.9
DBS-19	M21	Female	35–40	N-S	42.0	15.5	−8.2	8.2	3.2	7.6
DBS-20	M22	Female	25–30	E-W	44.0	16.3	−8.5	9.5	3.2	6.5
DBS-21	M23	Female	40–45	N-S	45.4	16.7	−9.5	9.6	3.2	3.5
DBS-22	M24	Male	30–35	E-W	44.5	16.4	−8.0	11.0	3.2	7.9
DBS-23	M25	Male	40±	E-W	44.6	16.3	−7.5	9.7	3.2	2.8
DBS-24	M26	Female	30±	N-S	41.9	15.5	−8.7	10.1	3.2	9.5
DBS-25	M28	Male	30±	N-S	42.3	15.7	−8.0	9.4	3.2	7.1
DBS-26	M29	Male	20–25	N-S	37.6	13.8	−9.4	8.7	3.2	5.6
DBS-27	M30	Female	30±	N-S	42.2	15.5	−7.9	9.9	3.2	6.3
DBS-28	M31	Male	25–30	E-W	40.4	15.1	−8.8	10.1	3.1	4.9
DBS-29	M32	Female	35±	E-W	43.0	15.7	−9.6	9.6	3.2	7.5
DBS-30	M33	Male	Adult	N-S	39.6	14.6	−9.9	9.2	3.2	8.1
DBS-31	M37	Female	30–35	N-S	39.6	14.6	−8.7	9.4	3.2	9.1
DBS-32	M38	Child	8±	E-W	42.4	15.8	−9.3	9.4	3.1	3.7
DBS-33	M39	Child	14±	N-S	44.5	16.4	−8.6	8.7	3.2	4.6
DBS-34	M40	Male	40±	N-S	43.6	16.1	−8.2	8.9	3.2	8.8
DBS-35	M41	Female	25–30	E-W	41.0	15.2	−8.3	8.0	3.2	5.0
DBS-36	M42	Female	25–30	E-W	44.2	16.4	−9.8	9.1	3.2	7.9
DBS-37	M43	Male	17±	N-S	41.6	15.4	−8.1	9.2	3.1	6.8
DBS-38	M44	Female	Adult	N-S	42.2	15.7	−14.7	8.0	3.1	7.2
DBS-39	M45	Female	40±	N-S	41.5	15.4	−10.7	8.1	3.2	11.0
DBS-40	M49	Female	40±	E-W	39.7	14.7	−9.5	10.7	3.2	6.9
DBS-41	M51	Female	35–40	E-W	42.2	15.6	−12.7	8.8	3.2	7.4

used for calibration. In addition, one collagen lab standard is inserted after every 20 samples. The δ^{13}C and δ^{15}N values of the collagen lab standard is −14.7±0.2‰ and 7.0±0.2‰ respectively. Moreover, carbon isotope ratios are expressed as δ^{13}C values relative to VPDB and nitrogen isotope ratios are expressed as δ^{15}N values relative to AIR. The long-term measurement precisions are better than ± 0.2‰ for both δ^{13}C and δ^{15}N. The isotopic data is presented in Table 1.

3. Result and discussion

3.1 The identification of collagen contamination

The purification of bone collagen is the first step to perform for isotopic analysis because the long-term burial conditions and diagenesis can give rise to variations of bones in biological as well as chemical composition(Price et al., 1992; Hedges, 2002). The collagen yield of the 41 samples ranged from 2.8% to 12.3%, and this is a little lower than what is found in modern bones (20%) (Ambrose, 1990). In addition, it is generally accepted that the bone collagen is well preserved when the contents of C and N as well as atomic C/N ratios range from 15.3% to 47%, 5.5% to 17.3% and 2.9 to 3.6, respectively (DeNiro, 1985). Thus, most of the Dabaoshan samples, except M8 (the contents of C and the atomic C/N ratio is not correct) meet the above criteria, which is appropriate for stable isotope analysis.

3.2 Isotopic analysis of human bone collagen

It is well known that the $\delta^{13}C$ values of C_3 plants range from −30‰ to −23‰ (averaging −26.5‰) while the $\delta^{13}C$ values of C_4 plants range from −9‰ to −16‰ (averaging −12.5‰) (Van der Merwe, 1982). Compared to the foods consumed, the $\delta^{13}C$ values of collagen in human (or animal) muscle and bone are 1‰ and 5‰ higher, respectively (DeNiro, 1978). Therefore, the $\delta^{13}C$ values in collagen can generally distinguish the category of foods consumed in a terrestrial food web, i.e., C_3 or C_4 based foods. For $\delta^{15}N$ values, they are typically enriched by 3–5‰ relative to the foods (Hedges et al., 2007; Sponheimer et al., 2003). Thus, higher $\delta^{15}N$ values of human collagen can generally indicate a higher trophic level and more consumption of animal protein if other complicated factors are excluded such as nutritional stress. Ideally, the environmental baseline should be established through the isotopic analysis of faunal bones, but when there is a lack of animal bones, the approximate value of 3‰ can be used to roughly estimate trophic levels. Namely, the $\delta^{15}N$ values of omnivorous animal are usually from 7‰ to 9‰, whereas, the $\delta^{15}N$ values of carnivorous animal are higher than 9‰ (Stanley, 1991; Bocherens et al., 1994).

Figure 2 presents a scatter plot of $\delta^{13}C$ and $\delta^{15}N$ values of all uncontaminated bone collagen in the Dabaoshan cemetery. According to the Figure 2, the $\delta^{13}C$ values of bone collagen are from −14.7‰ to −7.5‰, with a mean of −9.0 ±1.4‰ (n=40), suggesting the dietary structure is dominated by C_4 foods, like C_4 plants or the animal fed by C_4 plants. As to the $\delta^{15}N$ values, they range from 7.8‰ to 11.2‰ with an average of 9.6±0.9‰ (n=40), indicating a large quantity of animal protein was consumed. In summary, it can be concluded that the Dabaoshan people mainly relied on a large amounts of C_4-based animal proteins.

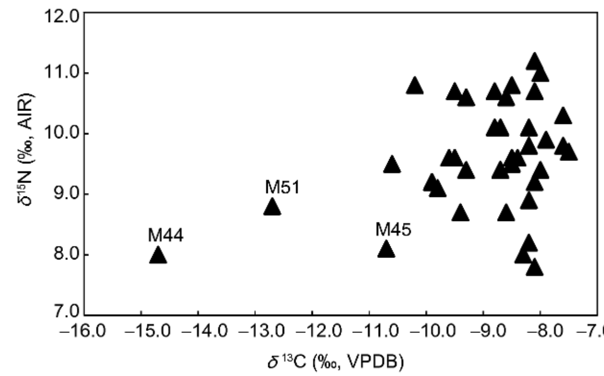

Figure 2 Scatter plot of human $\delta^{13}C$ and $\delta^{15}N$ values of bone collagen (n=40).

In addition, due to the large isotopic fluctuation in both carbon and nitrogen, a highly variable dietary pattern of the Dabaoshan community can be inferred. As shown in Figure 2, the collagen of M44, M51 and M45 have the lowest $\delta^{13}C$ values as well as the relatively depleted $\delta^{15}N$ values, which suggest that these three individuals may have consumed more C_3 plants than others. The notably different dietary pattern of M44, M51 and M45 might hint at different individual origins, and is discussed below. Furthermore, to better understand how genders and burial directions influence the Dabaoshan people's diets, we exclude the three isotopic outliers, M44, M51 and M45, and then make additional comparisons.

Table 2 presents the *T*-test results of the different genders and burial directions in the Dabaoshan community. As indicated in Table 2, there are no significant statistics differences in human isotopic data among individuals with different genders and burial directions, which suggest a relatively similar dietary structure.

3.3 The subsistence strategy of the Dabaoshan community

Located in present day Helingeer County, central-south Inner Mongolia, the Dabaoshan site is in the temperate semi-arid area of the continental monsoon climate with an annual temperature of 5.0℃ (Lan, 2007). During the Warring State Period to Han Dynasty, roughly from 2500 yr BP to 1700 yr BP, the climate of central-south Inner Mongolia was a litter colder according to the existing paleoenvironmental indexes, like pollen analysis and soil susceptibility (Zhao, 2011b; Xu et al., 2004). Generally, the C_4 biomass in natural vegetation can be ignored in the places where the average temperature is lower than 15℃ annually (Bird et al., 1997). In addition, the vegetation in temperate areas, like central-south Inner Mongolia, is mainly dominated by C_3 plants (Calvin, 1962). Therefore, although the specific environment research of the Dabaoshan site is still absent, the main composition of general natural vegetation should be C_3 plants near the Da-

Table 2 *T*-test results of individuals paleodiets of different genders and burial directions [a)]

Isotopic data	Genders			Burial directions		
	Male (n=20)	Female (n=15)	*T*-test values	North-south (n=25)	East-west (n=12)	*T*-test values
δ^{13}C (‰)	−8.6±0.9	−9.0±0.7	t=−1.25 P=0.54	−8.8±0.9	−8.7±0.8	t=−0.54 P=0.62
δ^{15}N (‰)	9.8±0.8	9.7±0.9	t=−0.40 P=0.83	9.7±0.9	9.7±0.8	t=−0.00 P=0.36

a) Significant difference exists when the value of P is lower than 0.05.

baoshan cemetery during Warring State Period.

The utilization of millet, broomcorn millet and foxtail millet (C_4 plants), were dated to 8000 BC in northern China (Zhao, 2006; Yang et al., 2012). The millet agriculture developed as the dominant source of diets during the Yang Shao Culture Period, roughly from 5000 BC to 3000 BC (Zhao, 2005, 2014; Zhang et al., 2010b; Hu et al., 2014; Atahan et al., 2014; Barton et al., 2009; Liu et al., 2012; Zhao, 2011a). Since the Longshan Culture Period, from 2500 BC to 2000 BC, wheat and barley (C_3 plants) began to be utilized and diverse crops systems were established in the Central Plain (Zhao, 2005, 2014; Li et al., 2013; Dodson et al., 2013). The cereals in this crops system generally included foxtail millet, broomcorn millet, wheat, bean and rice, and were named as the system of "five types of cereals" (Zhao, 2005, 2014; Li et al., 2013; Archaeometry Center of Chinese Academy of Social Sciences, 2011; Dodson et al., 2013). Later, the Xia, Shang and Zhou Dynasties, roughly from 2000 BC to 256 BC, the farming system of "five types of cereals" was widely fixed not only in traditional historical records but also in archaeological sites. However, referring to the published isotopic data of human and animal bones, millet still served as the staple source of diets in northern China (Zhao, 2005, 2014; Ren, 2005; Hou et al., 2012; Ling et al., 2010a, 2010b; Zhou et al., 2015).

Although flotation analysis at the Dabaoshan cemetery was not conducted, the rich historical records help to understand the crops systems in central-south Inner Mongolia. "Zhou Guan", an important historical document about this region, described "the land in Bing State is perfectly suited to grow five types of crops." Thus, as a part of the former Bing State, central-south Inner Mongolia should be ideal for the cultivation of millet. Besides, although the physical anthropological indexes have presented mixed characteristics between the ancient northern China type and ancient Central Plain type (Zhang, 2015), the burials goods and burial ceremony indicated more intensive influences from the Central Plain (College of History and Culture of Inner Mongolia Normal University et al., 2013; Yu et al., 2015). Therefore, as one of the most important cultural characteristics of the Central Plain, the intensive millet utilization might provide large amounts of C_4 food for Dabaoshan human diets, which is found here by the elevated δ^{13}C values of human bone collagen. Thus, millet agriculture, the intensive farming of millet plants and using the secondary products of millet to feed domestic animals, should play the extremely significant role in the Dabaoshan subsistence strategy.

In addition, Hanshu, the official historical literature of the Han Dynasty (206 BC to 23 AD) documented the Bing State is also rich in five breeds of domesticated animals, including horse, cattle, sheep, dog and pig. Moreover, the number of sheep, cattle and horse, as the important burial goods, significantly increased from late Spring Autumn Period in central-south Inner Mongolia. For example, the number of buried animals increased to 76% in the Xindianzi cemetery, Helingeer County and the percentage of buried animals in the Xiyuan cemetery was 100%, which suggest an advanced animal husbandry in this region (Wang et al., 2013; Chen et al., 2009; Bao, 2014; Liu, 1991). As to the Dabaoshan site, two bones of cattle were discovered (College of History and Culture of Inner Mongolia Normal University et al., 2013). Although these two bones were not collected, some activities of animal husbandry could be inferred. Besides, some physical anthropological indexes, like the degree of dental wear, incidence of hyposiagonarthritis and frequency of dental enamel hypoplasia also suggest that there was likely frequent animal protein consumption (Zhang, 2015). Most importantly, in this paper, the nitrogen isotopic data provide direct evidence about the high intake of animal protein in the Dabaoshan community. The average of nitrogen isotope ratios of 37 samples (3 outliers eliminated) is 9.7±0.8‰. Meanwhile, the δ^{15}N values of 32 samples are higher than 9‰, indicating a significant contribution of animal protein to the Dabaoshan human diets. In summary, the subsistence strategy of the Dabaoshan people mainly relied on millet-based agro-pastoralism. This intensive millet utilization served as the economic basis for the well-developed animal husbandry.

3.4 Analysis of isotopic outliers, genders and burial directions

First, as shown in Figure 2, individuals M44, M51 and M45 have the lowest δ^{13}C values as well as relatively depleted δ^{15}N values, which indicates that these three individuals may have consumed more C_3 plants than the others. Individuals M44 and M45 are buried with belt hooks and the tomb of M51 is in the east-west direction (College of History and

Culture of Inner Mongolia Normal University et al., 2013), which are almost similar to the other individuals. The only significant difference is that these three persons are females (Zhang, 2015). Therefore, we suspect the three individuals might be new immigrants before their death, but this speculation should be confirmed by more isotopic analysis such as Sulphur or Strontium.

Second, according to the existing physical anthropological research about the Dabaoshan persons, the social division of labor between different genders might be present (Zhang, 2015). Thus, *T*-tests were conducted to figure out the differences in isotopic data between males and females (Table 2). However, no significant dietary differences were found.

Finally, the different burial directions may also symbolize different sources of individuals, and this has been proposed by the burial ceremony research at the Maoqinggou cemetery and the Yinniugou cemetery (Inner Mongolian Relics Team, 1984; Cultural Relics Work Team of Inner Mongolia, 1986; Inner Mongolia Institute of Cultural Relics Archaeology et al., 2001; Yang et al., 2009). Specifically, the indigenous peoples, with the skeleton features of "ancient types of northern China" are always buried in an east-west direction, while, most individuals with "ancient types of Central Plain" are often interred in a north-south direction (Inner Mongolian Relics Team, 1984; Cultural Relics Work Team of Inner Mongolia, 1986; Inner Mongolia Institute of Cultural Relics Archaeology et al., 2001; Yang et al., 2009). As to the Dabaoshan site, these two burial patterns still co-existed, but the skeleton features of all the persons are highly mixed with the ancient types of northern China and ancient types of the Central Plain (Zhang, 2015). More importantly, the *T*-test results of the isotopic data between different burial patterns showed no statistical differences. In summary, because of the long-term fusion, the physical anthropological indexes and lives pattern have become increasingly similar in Dabaoshan community, whereas, the deeper cultural distinctions were still reserved just as diverse burial directions reflected.

3.5 The positive influence of agriculture to individual integration and cultural interaction in central-south Inner Mongolia

As introduced above, central-south Inner Mongolia is a key area for cultural communication and racial integration between the Central Plain and the northern steppe. In this paper, we provide a new perspective of lifeway variation to evaluate the positive effect of millet agriculture during these processes. Thus, a comprehensive comparison will be made (Figure 3) based on the published isotopic data of human bones collagen (Table 3), which all belonged to present Helingeer County from the Spring Autumn Period (SA, 770–476 BC) to Warring States Period (WS, 475–221 BC).

First, as presented in Figure 3, the elevated $\delta^{13}C$ values of

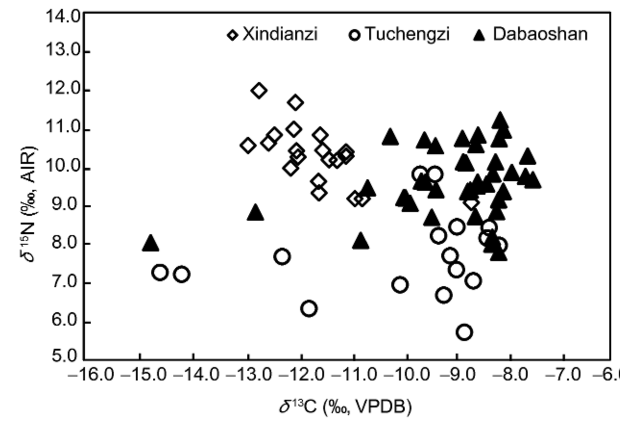

Figure 3 Isotopic data of human collagen from the Helingeer region during Eastern Zhou Period.

all the samples suggest the substantial consumption of C_4 foods (millet), although the background of the physical anthropological indexes and specific chronology are diverse (Gu, 2010; Zhang et al., 2006; Zhang, 2010). Second, the $\delta^{13}C$ values of the Tuchengzi and Dabaoshan individuals are much higher than the Xindianzi individuals, which means populations from the Tuchengzi and Dabaoshan sites are becoming increasingly reliant on millet agriculture as a result of growing immigrant waves and cultural inputs from the Central Plain. Moreover, the $\delta^{15}N$ values of Tuchengzi and Dabaoshan collagens are also lower than the Xindianzi ones which indicate the depression of animal husbandry during the intensification of millet farming.

As discussed above, the cultural patterns in central-south Inner Mongolia were characterized by either the Central Plain or northern steppe (Tian, 1997; Lin, 2008; Wuen, 2002; Wuenyuesitu, 2007; Yang, 2004, 2009; Yang et al., 2016; Cao, 2006; Wang, 2011; Shan, 2015). Although the different cultures and diverse populations with distinct skeletal features occupied this area successively, the millet agriculture always played an important role in the human diets, and becoming increasingly important with the northward expansions of the cultures of the Central Plain. Consequently, we proposed that millet agriculture might have significantly influenced this process.

The Xindianzi site was the largest cemetery in this region from the middle and late Spring Autumn Period to the early Warring States Period (Cao et al., 2009). The skeleton features, with the type of ancient Mongolian, revealed that the Xindianzi persons might come from the northern steppe. In addition, the chronological research of the burial goods was similar to those found in Tuva, Altai and Mongolia, which indicated the typical nomadic pastoral cultures widespread in the whole of the eastern Eurasian steppe (Cao et al., 2009; Wuen, 2002; Zhang et al., 2006; Zhang, 2010; Chen et al., 2009). However, supported by the isotopic data, the Xindianzi individuals consumed C_4 foods on a large scale

Table 3 Isotopic data of human collagen from central-south Inner Mongolia

Name	Culture	Age	Economy	Physical index	$\delta^{13}C$ (‰)	$\delta^{15}N$ (‰)	Reference
Dabaoshan	State of Zhao	Late WS	Agro-pastoralism	Mixed ancient northern China and ancient Central Plain	−9.0±1.4 (n=40)	9.6±0.9 (n=40)	This paper
Xindianzi	Nomadic remains	Late SA to Early WS	pastoralism	Ancient Mongolian	−11.6±0.9 (n=18)	10.3±0.8 (n=18)	Cao, 2009; Zhang, 2010
Tuchengzi	Mainly soldiers from Zhao State	Middle and late WS	Millet agriculture	Ancient Central Plain	−9.9±2.0 (n=17)	7.7±1.1 (n=17)	Gu, 2010

(Zhang et al., 2006; Zhang, 2010), which may come from the contribution of millet or the animals fed by millet. Recently, the millet contribution to pastoral paleodiets in the Eurasian steppe during early Iron age has been reevaluated through isotopic research, such as the analysis of the Tagar cultural cemeteries in the Minusinsk Basin and the study of Uyuk cultural sites in Tuva, which revealed the non-negligible proportion of millet in the agro-pastoralism economies (Murphy et al., 2013; Svyatko et al., 2013; Matuzeviciute et al., 2015; Lightfoot et al., 2015).

When it came to the middle and late Warring States Period, the Zhao State was in charge of the Helingeer region. On the one hand, the Zhao State delivered many soldiers to defend against the Huns, the powerful nomadic pastoral state in the north. On the other hand, lots of immigrants were encouraged to settle in this new territory (Inner Mongolian Relics Team, 1984; Cultural Relics Work Team of Inner Mongolia, 1986; Inner Mongolia Institute of Cultural Relics Archaeology et al., 2001; Archaeological Institute of Inner Mongolia et al, 2004; Archaeological Institute of Inner Mongolia, 2006; Gu, 2010; Yang et al., 2009; Shan, 2015). Based on these influential influxes from the Central Plain, a highly mixed pattern was formed not only in material cultures but also in ethnic compositions. As the typical military base of the Zhao State, the isotopic data of the Tuchengzi individuals showed more positive $\delta^{13}C$ values than the Xindianzi ones (Figure 3), which suggest the Tuchengzi persons relied on millet agriculture to a greater extent than the Xindianzi community. In addition, the large range of carbon isotope ratios of the Tuchengzi site may hint at the multiple sources of individuals, even coming from the different regions of the Central Plain. According to the documents of Zhao Aristocratic Family in Records of the Grand Historian, which is "Zhao Xi, one of the generals of Zhao State, led the army of Hu and Dai to conquer Zhongshan State", it can be inferred the individuals with elevated $\delta^{15}N$ values might be the local residents, possibly the Hu soldiers, as described in the historical literature (Lei, 2010; Zhang, 2002). In contrast, the homogenous isotopic data of the Dabaoshan individuals, even among different genders or diverse burial directions, indicated a very uniform diet after the long-term integration between Central Plain immigrants and local residents (Zhang, 2015). Thus, the millet agriculture likely served as the significant foundation of the agro-pastoralism economy of the Dabaoshan society.

In conclusion, millet agriculture was always a positive part of the subsistence strategy in the eastern Hohhot region since at least the Eastern Zhou Period. As a result of the northward expansion of immigrants and cultures from the Central Plain, the intensification of millet agriculture continuously occurred, which finally contributed to the great integration among central-south Inner Mongolian inhabitants, northern steppe pastoralism and central plain immigrants.

4. Conclusions

According to the carbon and nitrogen stable isotope analysis of bone collagen from the Dabaoshan cemetery, some conclusions can be reached as below.

(1) Individuals consumed a large amount of C_4-based animal protein, with subtle intake of C_3-based foods. In combination with the archaeological background, the subsistence strategy of the Dabaoshan community was an agro-pastoral economy, among which the millet agriculture served as an important position.

(2) The isotopic data shows no significant differences between different genders or burial directions, which indicates the relatively homogenous diet of the Dabaoshan community.

(3) Millet agriculture has a highly positive influence for the cultural integration and individual interaction in central-south Inner Mongolia during Eastern Zhou Period through the isotopic data comparison of another two sites, both of which are in the same region.

Finally, we should point out that the interpretation of this isotopic data may be inadequate due to the lack of animal bones. In addition, individual outliers, all aged females, should be further studied to understand the reason for their different dietary pattern. More research should be performed, like multi isotopic analysis, ancient DNA and physical anthropology studies, to shed light on the historical processes of human interaction and cultural communication in central-south Inner Mongolian region.

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